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ARTIFICIAL EYE FOR PEOPLE SUFFERING FROM LOW VISION

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Abstract- The retina is a thin layer of neural tissue that lines the back wall inside the eye. Some of these cells act to receive light, while others interpret the information and send messages to the brain through the optic nerve. This is part of the process that enables us to see. In damaged or dysfunctional retina, the photoreceptors stop working, causing blindness. By some estimates, there are more than 10 million people worldwide affected by retinal diseases that lead to loss of vision. The absence of effective therapeutic remedies for retinitis pigmentosa (RP) and age-related macular degeneration (AMD) has motivated the development of experimental strategies to restore some degree of visual function to affected patients. Because the remaining retinal layers are anatomically spared, several approaches have been designed to artificially activate this residual retina and thereby the visual system.

Keywords: Introduction; Literature survey; Pre-Processing and Segmentation; Feature Extraction; PCA method

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INTRODUCTION

At present, two general strategies have been pursued. The “Epiretinal” approach involves a semiconductor-based device placed above the retina, close to or in contact with the nerve fiber layer retinal ganglion cells. The information in this approach must be captured by a camera system before transmitting data and energy to the implant. The “Sub retinal” approach involves the electrical stimulation of the inner retina from the sub retinal space by implantation of a semiconductor-based micro photodiode array (MPA) into this location. The concept of the sub retinal approach is that electrical charge generated by the MPA in response to a light stimulus may be used to artificially alter the membrane potential of neurons in the remaining retinal layers in a manner to produce formed images.

o Literature survey

Early artificial eye makers may not have been creating prostheses at all, but rather decorations for religious and aesthetic purposes. In the millennia b.c., the people of Babylon, Jericho, Egypt, China, and the Aegean area all had highly developed arts and a belief in the afterlife. Radiographs of mummies and tombs have revealed numerous artificial eyes made of silver, gold, rock crystal, lapis lazuli, shell, marble, enamel, or glass. The Aztec and Inca also used artificial eyes for similar reasons. The skill of the Egyptian artists was so great that they were probably asked to create artificial eyes for human use, especially if the afflicted were royalty.

In 1579, the Venetians invented the first prosthesis to be worn behind the eyelids. These artificial eyes were very thin shells of glass, and therefore, did not restore the lost volume of an atrophied or missing eyeball. Because the edges were sharp and uncomfortable, the wearers had to remove the eyes at night in order to get relief from discomfort and to avoid breakage. After the invention of this glass shell prosthesis, there were no significant advances in artificial eyes until the nineteenth century. In the early 1800s, a German glassblower by the name of Ludwig Muller-Uri, who made life-like eyes for dolls, developed a glass eye for his son. Though it took 20 years to perfect his design, his success forced him to switch occupations to making artificial eyes full-time. In 1880, Dutch eye surgeon Hermann Snellen developed the Reform eye design. This design was a thicker, hollow glass prosthesis with rounded edges. The increase in thickness restored most of the lost volume of the eye and the rounded edges gave the patient much more comfort. Germany became the center for manufacturing glass artificial eyes.

Several years later in 1884, a glass sphere was implanted for the first time in the scleral cavity (the hollowed out interior of the white of the eyeball) after evisceration. An English doctor, Phillip Henry Mules, used the implant to restore lost volume and to give the prosthesis some movement. The sphere implant was subsequently adapted for the

enucleated socket as well. Many materials such as bone, sponge, fat, and precious metals have been used for implants since then, but 100 years later, the Mules sphere is still used in the majority of cases. Eye sockets with spheres within the scleral cavity following evisceration continue to result in excellent cosmetic results. For the enucleated socket another solution had to be found. During World War II, the glass eyes from Germany were unavailable, and therefore, the United States had to find an alternate material. In 1943, the U.S. Army dental technicians made the first plastic artificial eye. This material had the advantage of being unbreakable as well as malleable. Though these plastic prosthesis were impression-fitted, the back surface was not completely polished, leading to irritation of the eye socket due to a poor fit. An alternative was introduced by German-American glass blowers who were learning to make artificial eyes out of plastic using the Reform design. Though this type of artificial eye was an improvement, there were still problems with a persistent discharge of mucus from the eye socket. The wearers could sleep with the prosthesis in place, but were required to remove it every morning for cleaning. Despite these limitations, demand outpaced what the ocularists could handle, and therefore, a few large optical companies began mass producing the 12 most commonly used glass eye shapes. Called stock eyes, they have the disadvantage of not being properly fitted to the individual's eye socket. In the late 1960s the modified impression method was developed by American Lee Allen. This method included accurately duplicating the shape of the individual socket, as well as modifying the front surface of the prosthesis to correct eyelid problems. The back surface of the prosthesis must also be properly polished for an optimum fit.

- Visual System

The human visual system is remarkable instrument. It features two mobile acquisition units each has formidable preprocessing circuitry placed at a remote location from the central processing system (brain). Its primary task include transmitting images with a viewing angle of at least 140 deg and resolution of 1 arc min over a limited capacity carrier, the million or so fibers in each optic nerve through these fibers the signals are passed to the so called higher visual cortex of the brain.

Fig 2.1 block diagram of visual system

The nerve system can achieve this type of high volume data transfer by confining such capability to just part of the retina surface, whereas the center of the retina has a 1:1

ration between the photoreceptors and the transmitting elements, the far periphery has a ratio of 300:1. This results in gradual shift in resolution and other system parameters.

At the brain's highest level the visual cortex an impressive array of feature extraction mechanisms can rapidly adjust the eye's position to sudden movements in the peripherals filed of objects too small to see when stationary. The visual system can resolve spatial depth differences by combining signals from both eyes with a precision less than one tenth the size of a single photoreceptor.

- ***The EYE***

The main part in our visual system is the eye. Our ability to see is the result of a process very similar to that of a camera. A camera needs a lens and a film to produce an image. In the same way, the eyeball needs a lens (cornea, crystalline lens, vitreous) to refract, or focus the light and a film (retina) on which to focus the rays. The retina represents the film in our camera. It captures the image and sends it to the brain to be developed. The macula is the highly sensitive area of the retina. The macula is responsible for our critical focusing vision. It is the part of the retina most used. We use our macula to read or to stare intently at an object. About 130 million photoreceptors in the outermost layer (as seen from the center of the eye) of the transparent retina transform local intensity and color patterns into chemical and electrical signals which trigger activity of the many different retinal cells: horizontal cells, bipolar cells, amacrine cells, and ganglion cells.

The information is processed by astonishing amounts of serial and parallel pathways by in parts still unknown mechanisms. The information of these 130 million photoreceptors is compressed to the level of 1 million highly specialized GC-fibers. These 1 million fibers in the retina then form the optic nerve and transmit visual information to the visual cortex and its various areas in the back of the brain. The area of the retina that receives and processes the detailed images—and then sends them via the optic nerve to the brain—is referred to as the macula. The macula is of significant importance in that this area provides the highest resolution for the images we see. The macula is comprised of multiple layers of cells which process the initial "analog" light energy entering the eye into "digital" electro-chemical impulses. The retina is the innermost layer of the wall of the eyeball. Millions of light-sensitive cells there absorb light rays and convert them to electrical signals. The signals are sent through the optic nerve to the brain, where they are interpreted as vision.

- ***Retina***

Light first enters the optic (or nerve) fiber layer and the ganglion cell layer, under which most of the nourishing blood vessels of the retina are located. This is where the nerves begin, picking up the impulses from the retina and transmitting them to the brain. The light

is received by photoreceptor cells called rods (responsible for peripheral and dim light vision) and cones (providing central, bright light, fine detail, and color vision). The photoreceptors convert light into nerve impulses, which are then processed by the retina and sent through nerve fibers to the brain. The nerve fibers exit the eyeball at the optic disk and reach the brain through the optic nerve. Directly beneath the photoreceptor cells is a single layer of retinal pigment epithelium (RPE) cells, which nourish the photoreceptors. These cells are fed by the blood vessels in the choroids.

- ***Retinal Diseases***

There are two important types of retinal degenerative disease:

- Retinitis pigmentosa (RP), and
- Age-related macular degeneration (AMD)

Retinitis pigmentosa (RP) is a general term for a number of diseases that predominately affect the photoreceptor layer or "light sensing" cells of the retina. These diseases are usually hereditary and affect individuals earlier in life. Injury to the photoreceptor cell layer, in particular, reduces the retina's ability to sense an initial light signal. Despite this damage, however, the remainder of the retinal processing cells in other layers usually continues to function. RP affects the mid-peripheral vision first and sometimes progresses to affect the far-periphery and the central areas of vision. The narrowing of the field of vision into "tunnel vision" can sometimes result in complete blindness. Age-related macular degeneration (AMD) refers to a degenerative condition that occurs most frequently in the elderly.AMD is a disease that progressively decreases the function of specific cellular layers of the retina's macula. The affected areas within the macula are the outer retina and inner retina photoreceptor layer. Patients with macular degeneration experience a loss of their central vision, which affects their ability to read and perform visually demanding tasks. Although macular degeneration is associated with aging, the exact cause is still unknown. Together, AMD and RP affect at least 30 million people in the world. They are the most common causes of untreatable blindness in developed countries and, currently, there is no effective means of restoring vision.

- Epi-Retinal Implants

In the EPI-RET approach scientists had developed a micro contact array which is mounted onto the retinal surface to stimulate retinal ganglion cells. The information in this approach must be captured by a camera system before transmitting data and energy to the implant. A tiny video camera is mounted on eyeglasses and it sends images via radio waves to the chip. The actual visual world is captured by a highly miniaturized CMOS camera embedded

into regular spectacles. The camera signal is analyzed and processed using receptive field algorithms to calculate electric pulse trains which are necessary to adequately stimulate ganglion cells in the retina. This signal together with the energy supply is transmitted wireless into a device which is implanted into the eye of the blind subject. The implant consists of a receiver for data and energy, a decoder and array microelectrodes placed on the inner surface of the retina. This micro chip will stimulate viable retinal cells. Electrodes on microchip will then create a pixel of light on the retina, which can be sent to the brain for processing. The main advantage of this is that it consists of only a simple spectacle frame with camera and external electronics Communicates wirelessly with microchip implanted on retina programmed with stimulation pattern .

The issues involved in the design of the retinal encoder are:

- Chip Development
- Biocompatibility
- RF telemetry and Power systems

- ***Chip Development***

The design of an epiretinal encoder is more complicated than the sub retinal encoder, because it has to feed the ganglion cells. Here, a retina encoder (RE) outside the eye replaces the information processing of the retina. A retina stimulator (RS), implanted adjacent to the retinal ganglion cell layer at the retinal 'output', contacts a sufficient number of retinal ganglion cells/fibers for electrical stimulation. A wireless (Radio Frequency) signal- and energy transmission system provides the communication between RE and RS. The RE, then, maps visual patterns onto impulse sequences for a number of contacted ganglion cells by means of adaptive dynamic spatial filters. This is done by a digital signal processor, which, handles the incoming light stimuli with the master processor, implements various adaptive, antagonistic, receptive field filters with the other four parallel processors, and generates asynchronous pulse trains for each simulated ganglion cell output individually. These spatial filters as biology-inspired neural networks can be 'tuned' to various spatial and temporal receptive field properties of ganglion cells in the primate retina.

- ***Biocompatibility***

The material used for the chips and stimulating electrodes should satisfy a variety of criteria’s. They must be corrosion-proof, i.e. bio stable.

- The electrodes must establish a good contact to the nerve cells within fluids, so that the stimulating electric current can pass from the photo elements into the tissue.
- It must be possible to manufacture these materials with micro technical methods and.
- They must be biologically compatible with the nervous system

- ***RF Telemetry***

In case of the epiretinal encoder, a wireless RF telemetry system acts as a channel between the Retinal Encoder and the retinal stimulator. Standard semiconductor technology is used to fabricate a power and signum receiving chip, which drives current through an electrode array and stimulate the retinal neurons. The intraocular transceiver processing unit is separated from the stimulator in order to take into account the heat dissipation of the rectification and power transfer processes. Care is taken to avoid direct contact of heat dissipating devices with the retina.

Enhancement System (LVES) developed at Johns Hopkins. LVES- a video magnification system for people with low vision. This Can zoom from 2 inches to infinity. Can magnify 9x at distance and 25x near. Visually impaired people must have a system customized to their own visual deficiencies. But it will be available only after 2010. Low vision described was no better vision than 20/40 when corrected.

- ***Sub Retinal Implantation***

The subretinal approach is based on the fact that for instance of retinitis pigmentosa; the neuronal network in the inner retina is preserved with a relatively intact morphology. Thus, it is appropriate for excitation by extrinsically applied electrical current instead of intrinsically delivered photoelectric excitation via photoreceptors. This option requires that basic features of visual scenes such as points, bars, edges, etc. can be fed into the retinal network by electrical stimulation of individual sites of the distal retina with a set of individual electrodes.

Subretinal approach is aiming at a direct physical replacement of degenerated photoreceptors in the human eye, the basic function of which is very similar to that of solar cells, namely delivering slow potential changes upon illumination. The quantum efficiency of photoreceptor action, however, is 1000 times larger than that of the corresponding technical de-vices. Therefore the intriguingly simple approach of replacing degenerated photoreceptor. by artificial solar cell arrays has to overcome some difficulties, especially the energy supply for successful retina stimulation . On the ‘back’ side of the retina,

photoreceptors (rods and cones) are excited by the incoming light and deliver gradual potential changes to the inner retina layers. The path of the electrical signals is then opposite to that of the incoming light. The main problem in diseases like retinitis pigmentosa or macula degeneration is the loss of photoreceptors or photoreceptor function, whereas the signal processing path in the inner retina is remaining intact. This gives us the chance to place a micro photo diode array (MPDA) in the subretinal space, which may then electrically stimulate remaining photoreceptor or bipolar cells. Appropriate surgical techniques have recently been developed and tested. It's believed that the so evoked retinal activity leads to useful sensations if the retinal output reveals the topography of the image feature and is projected retinotopically correct to the visual cortex. In addition, the sampling density of a sub retinal device could be designed to match that of the remaining photoreceptor or bipolar cell matrix, thereby providing a potentially high-resolution input to the retina. Implant chips have been tested both in vitro and in vivo to assess their bio-stability. In vitro stability (in buffered saline solution) is excellent even for periods as long as 2 years. In vivo, however, the passivation layer could withstand the biological environment for up to about six months only. In contrast, the electrodes made of titanium nitride showed excellent biostability over more than 18 months in vivo. These are the results of vitro and vivo tests conducted by the scientists in Retinal Implant Research centre.

- ***In Vitro-Tests***

In order to evaluate parameters for subretinal electrical stimulation scientists established new in-vitro methods for electrical multisite stimulation of explanted retinas and multichannel recording of retinal activity. The aim of the study, which is still carried out at the NMI is to find stimulation paradigms that are suitable to evoke spatially structured ganglion cell activity within a safe operational range of the electrodes and the tissue and with an adequate dynamic range of the retinal output.

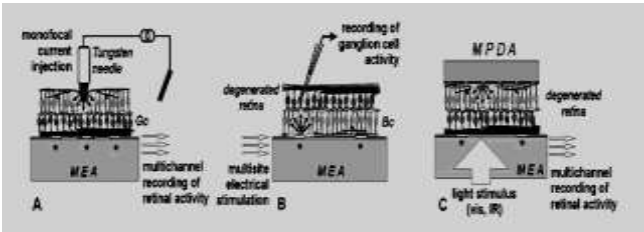

Fig 3.1 Functional electrical retina stimulation in vitro.

Mono-focal distal current injection: Pieces of whole mount retinas are attached to a microelectrode array (MEA) with the ganglion cell side facing the transparent glass plate and its embedded planar electrodes (asterisks). A tungsten electrode is lowered into the

distal side of the retina. Monopolar charge balanced current pulses are applied (bundle of arrows from top). Fig B Shows Multisite charge injection: With the ganglion cell side up, multifocal stimulation of the distal retina side is obtained by applying voltage pulses to a variable number of electrodes of the MEA (bundle of arrows from bottom). The retinal response is recorded from ganglion cell bodies with a glass pipette. Fig (C) Sandwich preparation technique: A MPDA prototype chip is placed onto the distal retina side and is illuminated with flashes of light (arrow from bottom). Multi-unit ganglion cell activity evoked by the light generated photodiode current (bundle of arrows from top) is recorded with several MEA electrodes in parallel. Retina segments from chicken or blind RCS rats were adhered to a microelectrode array (MEA) with 60 substrate integrated planar electrodes (diameter 10 µm, spacing 100 µm) either for distal stimulation or proximal recording. In the preparation where the photoreceptor side faces the MEA, retinal activity was evoked by stimulation with different geometrically defined voltage patterns. With this method, we were able to investigate the dependence of the retinal network response on the strength, shape and location of distally injected spatial charge patterns. This arrangement well imitates the *in-vivo* situation of a subretinal implant with embedded stimulation electrodes. They found that application of different spatio-temporal voltage pattern via the electrode array resulted in well-ordered spatio-temporal activity pattern in the retinal network. Median charge delivery at threshold was 0.4 nC/pulse/electrode (charge density 500 µC/cm²). The operational range for modulating the spike activity with distally injected charge covers about one to two orders of magnitude (charge in nC). The spatial resolution was 100 - 200 µm. The results also indicate that ganglion cells respond to charge injection within a circumscribed area with center and surround.

- ***Threshold and operational range for subretinal stimulation***

Evoked retinal response related to the amount of injected charge. (A) Raster plot (40 trials) and cumulative response histogram (bin width 1 ms) to a single voltage pulse with 0.5 ms duration and increasing amplitude, applied via a platinized gold electrode to a chicken retina sample. In the histograms the number of spikes from 40 trials is given. (B) Relative ganglion cell response in a 40 ms window after pulse onset plotted against charge injected per pulse and electrode. At the upper axis the related voltage level and peak current are given. The error bars indicate the standard deviation of the number of spikes per trial within the analyzing window. The colored triangle indicates the operational range between the 10% and 90% response level. (C) Scatter diagram showing the charge thresholds for spot stimulation (n = 10). The line represents the median value (0.43 nC).

The experiments revealed that in a partly degenerated neuronal network information processing capabilities are present and can be activated by artificial inputs. This open up promising perspectives not only for the development of sub-retinal implanted stimulation

devices as visual prostheses but also for the entire field of neurobionics and neuro-technology.

- ***WORKING OF ASR***

The ASR™ microchip is a silicon chip 2mm in diameter and 25 microns thick, less than the thickness of a human hair. It contains approximately 5,000 microscopic solar cells called "micro photodiodes," each with its own stimulating electrode. These micro photodiodes are designed to convert the light energy from images into electrical chemical impulses that stimulate the remaining functional cells of the retina in patients and rp type or devices.

The ASR microchip is powered solely by incident light and does not require the use of external wires or batteries. When surgically implanted under the retina—in a location known as the "subretinal space"—the ASR chip is designed to produce visual signals similar to those produced by the photoreceptor layer. From their sub retinal location, these artificial "photoelectric" signals from the ASR microchip are in a position to induce biological visual signals in the remaining functional retinal cells which may be processed and sent via the optic nerve to the brain. In preclinical laboratory testing, animal models implanted with the ASRs responded to light stimuli with retinal electrical signals (ERGs) and sometimes brain-wave signals (VEPs). The induction of these biological signals by the ASR chip indicated. When a diode is reverse biased the electrons &holes move away from PN junction. If the photo diode is exposed to a series of light pulses the photon generated minority carriers must diffuse to the junction &should be swept across to the other side in a very short time. Therefore its decided that he width of the depletion region is be large enough that most of the photons are absorbed within the depletion region rather than in the neutral PN junction region. Photodiode can work in two modes. One in which the external circuit delivers power to the device other in which device gives power to the external circuit. Therefore it can be called as a solar cell. The ASR is powered solely by the incident light &does not require the use of external wires or batteries. When surgically implanted under the retina in a location known as subretinal space the ASR is designed to produce visual signals similar to those produced by the photoreceptor layer. Thus a photodiode produces a voltage corresponding to the light energy incident on it. Solar cells in the device's microchip are supposed to replace the function of the retina's light-sensing cells that have been damaged by disease. The ASR microchip relies on the ability to stimulate the remaining functional cells within a partially degenerated inner or neuro retina. As a result, the ASR chip will not be able to assist patients with conditions where the retina or visual pathway is more substantially damaged.

- **Cortical Implants**

The new visual prosthesis produces black and white display of visual cortex "phosphenes" analogous to the images projected on the light bulb arrays of some sports stadium scoreboards. The system was primarily designed to promote independent mobility, not reading. It has a battery powered, electronic interface that is RF isolated from line currents for safety. This interface can replace the camera, permitting the volunteer to directly watch television and use a computer, including access to the Internet. Because of their potential importance for education, and to help integrate blind people into the workforce, such television, computer, and Internet capabilities may prove even more valuable in the future than independent mobility. First of all passing an electric current through a single electrode into the visual cortex causes a blind subject to see a point of light called a phosphene. The visual scene before the subject will be encoded by miniature video camera attached to a pair of eye glasses. The resulting video signals will be processed by custom circuitry. The processed signals pass across the skull to an array of electrodes implanted in the primary visual cortex. Relaying the electric signals to the cortical implant could be accomplished by two methods- conductive and inductive. In the former connectors are attached to the cranium and provide access to the external circuitry with the later a transformer is formed with one coil under the skin and the other one on the outside.

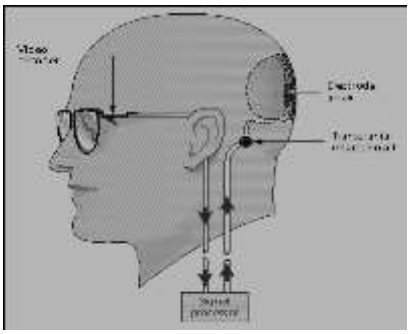

Fig 4.1 Cortical Implant

A platinum foil ground plant is perforated with a hexagonal array of 5 mm diameter holes on 3 mm centers, and the flat platinum electrodes centered in each hole are 1 mm in diameter. This ground plane keeps all current beneath the dura. This eliminates discomfort due to dural excitation when stimulating some single electrodes (such as number 19) and when other arrays of electrodes are stimulated simultaneously. The ground plane also eliminates most phosphene interactions when multiple electrodes are stimulated simultaneously, and provides an additional measure of electrical safety that is not possible when stimulating between cortical electrodes and a ground plane outside the skull. Each electrode is connected by a separate Teflon insulated wire to a connector contained in a carbon percutaneous pedestal. When stimulated, each electrode produces 1-4 closely

spaced phosphenes. Each phosphene in a cluster ranges up to the diameter of a pencil at arm's length. Neighboring phosphenes in each cluster are generally too close to the adjacent phosphenes for another phosphene to be located between them. Indicate the primary visual cortex (area 17) would permit placement of 256 surface electrodes on 3 mm centers on each lobe in most humans (512 electrodes total.

- **CONCLUSION**

It is paper is directed towards the people who are visually impaired. People suffering from low vision to, people who are completely blind will benefit from this project. The findings regarding biocompatibility of implant materials will aid in other similar attempts for in human machine interface. Congenital defects in the body, which cannot be fully corrected through surgery. Implementation of an Artificial Eye has advantages. An electronic eye is more precise and enduring than a biological eye and we cannot altogether say that this would be used only to benefit the human race. In short successful implementation of a bioelectronic eye would solve many of the visual anomalities suffered by human's to deth.

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